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(54) **An ion implantation apparatus**

Ionen-Implantationsgerät

Appareil d'implantation ionique

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- **NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH, SECTION B : BEAM INTERACTIONS WITH MATERIALS AND ATOMS, vol. 21, 1987, Amsterdam, NL, pp. 314-316; K. MATSUDA et al.: "Large Diameter Ion Beam Implantation System"**
- **REVIEW OF SCIENTIFIC INSTRUMENTS, vol. 55, 1984, New York, US, pp. 1229-1234; M.J. RHEE : "Compact Thomson Spectrometer"**
- **JAPANESE JOURNAL OF APPLIED PHYSICS, vol. 29, 1990, Tokyo, JP, pp. 1841-1845; T. YAMAMOTO et al.: "Thomson Parabola Ion Analyzer With Quick Data Acquisition"**
- **JOURNAL OF APPLIED PHYSICS, vol. 59, no. 6, 1986, New York, US, pp. 1890-1903; B.E. THOMPSON et al.: "Ion Bombardment Energy Distributions In Radio-Frequency Glow-Discharge Systems"**

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to an ion implantation apparatus, and more particularly to an ion implantation apparatus used for fabricating semiconductor devices such as a thin film transistor.

2. Description of the Prior Art:

Among the processes for fabricating various semiconductor devices, ion implantation is indispensable and extremely important as a process for doping a semiconductor with impurities. A substrate on which semiconductor devices are formed has become large today since an image sensor, a liquid crystal display and the like have become large-sized and the productivity thereof has improved. As a result, an ion implantation apparatus for implanting ions on a large area is desired.

An ordinary ion implantation apparatus comprises an ion source, a mass spectrometer and an ion accelerator. Ions generated at the ion source are allowed to pass through the mass spectrometer to eliminate ions unnecessary to the ion implantation, and only the selected ions are accelerated by the ion accelerator. The accelerated ions are generally implanted into a substrate in a shape of an ion beam having a diameter of several mm. A dose of the ion implanted into the substrate can be determined by measuring an ion current flowing through the substrate.

When the ions are implanted into a large area substrate using the above described ion implantation apparatus, it is necessary to either scan the substrate mechanically or scan the ion beam electrically because the area of the substrate is large as compared with the diameter of the ion beam. This results in a problem that a larger substrate requires a longer time for the ion implantation. Moreover, providing a mechanical or an electrical scanning means causes another problem that the ion implantation apparatus becomes complicated, large-sized and expensive.

One of the techniques in which ions are easily implanted into a large substrate without the above-mentioned mechanical or electrical scanning means is disclosed in the Japanese Laid Open Patent Publication No. 63-194326. According to this prior art, ions generated by using a plasma discharge as the ion source are accelerated at a low voltage without allowing them to pass through the mass spectrometer and implanted into a substrate which has been heated to a predetermined temperature in a shower-like shape. Since the generated ions do not pass through the mass spectrometer, all kinds of generated ions including unnecessary ones are implanted. Furthermore, the dose of all the kinds of the ions is measured as the ion current. Therefore, in the prior art, the precise dose of a desired kind of ions can not be measured.

For example, in the ion implantation with the above ion implantation apparatus using PH_3 gas diluted with H_2, P^+ and H^+ are generated. Since only P^+ makes the substrate conductive, the dose of P^+ must be controlled. However, with this ion implantation apparatus, only the total dose of all the kinds of the ions including P^+ and H^+ can be measured. The dose of the desired kind of ions can only be experientially estimated based on the total dose. In such a case the control of the dose of a desired kind of ions is very inaccurate.

SUMMARY OF THE INVENTION

In one aspect, the present invention provides the ion implantation apparatus defined by claim 1. The dependent claims 2 and 3 relate to embodiments of the invention.

In another aspect, the present invention provides the method for controlling an ion implantation dose defined by claim 4.

The preambles of claims 1 and 4 reflect the state of the art according to the following document:

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH, SECTION B: BEAM INTERACTIONS WITH MATERIALS AND ATOMS,

Vol. 21. 1987, AMSTERDAM, NL, pages 314-316 MATSUDA ET AL. 'LARGE DIAMETER ION BEAM IMPLANTATION SYSTEM'.

The above document describes a large diameter ion beam implantation system having a Faraday cup array for monitoring the ion beam spatial profile.

A known Thomson spectrometer system for use in ion diagnosis is known from the following document:

REVIEW OF SCIENTIFIC INSTRUMENTS, Vol. 55, 1984, NEW YORK, US, pages 1229-1234 RHEE 'COMPACT THOMSON SPECTROMETER'.

According to the ion implantation apparatus and method of the invention, the irradiation time of a desired kind of ions may be conveniently determined by the numbers of desired ions determined by the electromagnetic ion energy analyzer and of the total ions determined by the charge collector, respectively, thereby controlling doping of a substrate with impurities. Therefore, it is possible to dope the substrate with impurities uniformly to fabricate a semiconductor device with uniform characteristics. This results in increasing the yield in fabricating the semiconductor devices.

Thus, the invention disclosed herein makes possible the advantage of providing ion implantation for fabricating a semiconductor device with uniform characteristics by controlling the number of ions necessary to an ion implantation into a large substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure **1** is a sectional schematic view of an ion implantation apparatus according to the present invention; and

Figure **2** is a diagram for showing an operation of a means for measuring a number of ions used in the ion implantation apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure **1** is a sectional schematic view of an ion implantation apparatus of the present invention. The ion implantation apparatus shown in Figure **1** comprises a plasma source **25** for generating ions, an ion accelerator **9** for accelerating the generated ions, a substrate holder **11** for holding a substrate, an electromagnetic ion energy analyzer **14** for measuring a number of a desired kind of ions and a charge collector **13** for measuring a current density of all the kinds of the ions.

The plasma source **25** includes a cylindrical chamber **2** for keeping a plasma and high frequency electrodes **4a** and **4b** respectively provided on a top and a side of the cylindrical chamber **2**. The high frequency electrode **4a** on the top of the cylindrical chamber **2** has a diameter of 60 cm. A high frequency power supply 3 for exciting a plasma is connected to the high frequency electrodes **4a** and **4b**. A gas inlet 1 for introducing a gas as an ion source is provided in a center of the high frequency electrode **4a** on the top of the cylindrical chamber **2**. A magnet **5** is provided on the outside of the high frequency electrode **4b** on the side of the cylindrical chamber **2** so as to aid effective generation of ions and adjust the shape of the plasma. A high frequency electric power of 13.56 MHz is applied to the high frequency electrodes **4a** and **4b** at 100 to 200 W and a pressure in the chamber **2** is maintained at 1.33×10^{-3} to 1.33×10^{-1} Pa (10^{-5} to 10^{-3} Torr). Thus a plasma is generated and the introduced gas is partially ionized in the cylindrical chamber **2**.

The ion accelerator **9** comprises four meshy electrode plates **9a, 9b**, **9c** and **9d** disposed parallel to each other. The first electrode plate **9a** is provided at a bottom of the cylindrical chamber **2** as the plasma source. These four electrode plates **9a, 9b, 9c** and **9d** are insulated by an insulator **10** and kept with appropriate intervals therebetween. A first ion acceleration power supply **6** is connected between the first and the second electrode plates **9a** and **9b**. A voltage caused by the first ion acceleration power supply **6** derives the ions generated at the plasma source into the ion accelerator **9**. A second ion acceleration power supply **7** is connected between the second and the third electrode plates **9b** and **9c**. A voltage caused by the second ion acceleration power supply **7** further accelerates the derived ions. The ions are accelerated and proceed vertically to the electrode plates **9a**, **9b**, **9c** and **9d**. A deceleration power supply **8** for controlling secondary electrons is connected between the third and the fourth electrode plates **9c** and **9d**.

A substrate **12** is mounted on the substrate holder **11**, and the ions accelerated in the ion accelerator **9** irradiate the substrate **12**. The distance between the fourth electrode plate **9d** and the substrate **12** is about 50 cm. The ion implantation apparatus of the present invention is provided with a rotation mechanism for rotating the substrate holder **11** so as to implant the ions into the substrate uniformly. In the ion implantation apparatus with this structure, it is possible to implant ions uniformly into a substrate with a size up to 30 cm x 30 cm.

The electromagnetic ion energy analyzer **14** comprises apertures **15a** and **15b** with an aperture diameter of 100 μm, a pair of electrodes **16** with a size of 4 cm x 5 cm, respectively, for generating an electrical field, a pair of magnets **17** comprising a north pole and a south pole with a size of 4 cm x 5 cm, respectively, for generating a magnetic field and a detection area **18** for detecting the ions. The detection area **18** has a size of 20 cm x 20 cm and is disposed 10 cm away from the aperture **15b**. One of the electrodes **16** has a terminal **19** for applying a voltage thereto. The electrodes **16** and the magnets **17** are provided in a manner that the electric field and the magnetic field are formed vertically to a direction in which the ions irradiate (hereinafter called the "ion incident direction"). (The ion incident direction is parallel to a z-axis in Figure **2**.) The distance between the pair of the electrodes **16** and the magnets **17** is adjusted so as to generate an electric field of 100 kV/m between the electrodes **16** and a magnetic field of 3.0×10^{-2} T (300 gauss) between the magnets **17**. The ions having passed through the apertures **15a** and **15b** further pass through the electric field and the magnetic field generated by the electrodes **16** and the magnets **17**, respectively, to reach the detection area **18**.

The charge collector **13** is provided in a position irradiated by the ions the amount of which is practically equal to that of the ions irradiating through the apertures **15a** and **15b** of the electromagnetic ion energy analyzer **14** per unit time. The charge collector **13**, which is called a Faraday cup as well, measures a charge of the irradiating ions as a current density.

Figure **2** schematically shows a principle of the measurement by the electromagnetic ion energy analyzer **14**, which will now be described by illustrating an example in which H^+, B^+ and P^+ enter the electromagnetic ion energy analyzer **14**.

Broken lines **20**, **21** and **22** show points on a surface of the detection area **18** at which each kind of ions arrives. When an energy for the implantation is determined, one point on the surface of the detection area **18** is settled per each kind of ion species as an impinge position. On a coordinate having the ion incident direction through the apertures **15a** and **15b** as the z-axis and the detection area **18** as the x-y plane, the impinge positions are represented by a parabola which satisfies the following formula:

$$y = k\ (M / Z)\ x^2$$

wherein M is a mass of an ion, Z is a number of a valence of the ion and k is a constant determined by a design of the electromagnetic ion energy analyzer **14**. As is evident from the formula, each kind of the ion arrives at a different position on the detection area **18** by a force applied from the electric and magnetic fields depending upon the mass and the charge of the ions.

When PH_3 diluted with H_2 is used as an introduced gas, H^+ and P^+ are generated at the plasma source. When the generated H^+ and P^+ are accelerated at a voltage of 100 kV, H^+ and P^+ reach only points **23** and **24**, respectively. The distance between the points **23** and **24** on the detection area **18** is about 3 cm. A charge collector other than the charge collector **13** is provided on such a determined position as a means for detecting a desired kind of ions, thereby measuring the current density caused by the desired kind of ions. In this example, since only P^+ is necessary to the ion implantation, the current density of P^+ alone can be measured when a charge collector is provided on the point **24**. In this way, the dose of the ions necessary to the ion implantation can be measured. Moreover, when a total current density of H^+ and P^+ is measured at the same time by the charge collector **13**, a ratio of P^+ necessary to the ion implantation to all the kinds of the ions, H^+ and P^+ can be obtained. The dose of P^+ can be controlled when an ion irradiation time is determined by using the obtained ratio.

When the ions are implanted with a different energy, the charge collector is moved along the afore-mentioned parabola depending upon the energy to measure a current density of the desired kind of ions. The charge collector is automatically moved along the x- and y-axes depending upon the charge and the mass of the ion to be detected and the acceleration energy of the ion, therefore such a series of operations can be conducted automatically and easily to control the amount of the ion necessary to the ion implantation.

In the above-mentioned example, the electric field and the magnetic field are generated vertically to the ion incident direction. However, the ions can be separated depending upon the kind thereof and an energy for the ion implantation as far as the electric field and the magnetic field generated by the electrodes **16** and the magnets **17**, respectively, are not parallel to the ion incident direction, since such electric and magnetic fields have components vertical to the ion incident direction. Moreover, in the above-mentioned example, the acceleration and the proceeding of the ions are in the same direction. However, in other structures, the ions can be accelerated in different directions from the proceeding direction thereof. Even in such a case, the ions can be separated depending upon the mass and the charge thereof and the implantation energy by generating the electric and magnetic fields having components vertical to the incident direction of the ions entering the electromagnetic ion energy analyzer **14**.

In the present example, the total current density of H^+ and P^+ is measured by the charge collector **13**, and the current density of P^+ is measured by the electromagnetic ion energy analyzer **14**. Thus, the ratio of P^- to all the kinds of the ions is obtained. However, the ion irradiation time can be determined only with the electromagnetic ion energy analyzer **14**.

Moreover, in the example, the number of the ions having reached the detection area **18** is measured by the charge collector, but it can be measured by using a film. When a film is provided on the detection area **18**, the ions arrive at different positions on the film depending upon the mass and the charge thereof. By measuring a density of the trace of the ions on each impinge position, the ratio of each kind of the ions can be obtained. The dose of the ions necessary to the ion implantation can be controlled by using the obtained ratio.

With a simple structure as is shown in the above described example, the ions can be implanted into a large substrate, and a dose of the ions to be implanted can be easily controlled.

In this way, ions can be implanted into a large substrate, controlling the dose thereof accurately, according to the present invention. As a result, a semiconductor device with uniform characteristics can be fabricated with an increased yield.

Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope of the claims. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly construed.

Claims

1. An ion implantation apparatus comprising:

   a plasma source (25) for generating ions;
   an ion accelerator (9) for accelerating the ions;
   a substrate holder (11) provided at a position which the accelerated ions irradiate; and
   a charge collector (13) provided at a position adjacent the substrate holder (11) which the accelerated ions irradiate;
   characterized:
   by an electromagnetic ion energy analyzer (14) provided at a position adjacent the substrate holder (11) which the accelerated ions irradiate and including a field generating means (15a,15b,16,17) for generating an electric field and a magnetic field having components orthogonal to the ion incident direction, and a measuring means (18) for measuring a number per unit time of a desired kind of the ions, the measuring means having a detection area including different points at which the ions having passed through the electric field and the

magnetic field arrive depending upon a mass and a charge of the ions; and
in that the charge collector (13) is arranged for measuring a number of the ions the amount of which is practically equal to that of the total ions irradiating the electromagnetic ion energy analyzer (14) per unit time.

2. An ion implantation apparatus according to claim 1, wherein the measuring means (18) is adapted to measure a current density of a desired kind of ions having passed through the electric field and the magnetic field.

3. An ion implantation apparatus according to claim 1, wherein the measuring means (18) has a film for detecting traces of the radiating ions which pass through the electric field and the magnetic field and reach the film.

4. An ion implantation method in which ions are accelerated from a plasma source (25) and caused to impinge on a target substrate (12), characterized in that ion dosing of the substrate (12) with a particular desired species of ion in the plasma is controlled in accordance with the outputs of (i) an electromagnetic ion energy analyzer (14) which detects said desired ion species after separating them from a sample of the mixture of ions accelerated from the plasma, and (ii) a charge collector (13) which receives a corresponding sample of the mixture of ions accelerated from the plasma, each sample corresponding to the ions irradiating said target substrate, by calculating a ratio of the number per unit time of said desired ion species measured by the electromagnetic ion energy analyzer (14) to a number per unit time of all kinds of the ions in the sample measured by the charge collector (13).

Patentansprüche

1. Gerät zur Ionenimplantation mit:

einer Plasmaquelle (25) zur Ionengeneration;
einem Ionenbeschleuniger (9) zur Beschleunigung der Ionen;
einem Substrathalter (11) an einer durch die Ionen bestrahlten Position; und
einer Ladungssammelelektrode (13) an einer durch die Ionen bestrahlten Position neben dem Substrathalter (11);
gekennzeichnet durch:
einen elektromagetisch arbeitenden Ionenenergie-Analysator (14) an einer durch die Ionen bestrahlten Position neben dem Substrathalter (11) mit einem Feldgenerator (15a, 15b, 16, 17) zum Generieren eines elektrischen und eines magnetischen Feldes mit zur Ioneneinfallrichtung orthogonalen Teilkräften, und einem Meßgerät (18) zum Messen einer Anzahl einer bestimmten Ionenart pro Zeiteinheit, das Meßgerät hat einen Erfassungsbereich, der verschiedene Punkte einschließt, an denen die Ionen, die das magnetische und das elektrische Feld passiert haben, abhängig von ihrer Masse und Ladung ankommen; und
dadurch, daß die Ladungssammelelektrode (13) so angeordnet ist, daß sie eine Anzahl der Ionen mißt, die praktisch gleich zu der von allen den Ionenenergie-Analysator (14) bestrahlenden Ionen pro Zeiteinheit ist.

2. Gerät zur Ionenimplantation nach Anspruch 1, **dadurch gekennzeichnet**, daß das Meßgerät (18) darauf ausgelegt ist, einen Dichtestrom einer gewünschten Art von Ionen zu messen, die das elektrische und das magnetische Feld passiert haben.

3. Gerät zur Ionenimplantation nach Anspruch 1, **dadurch gekennzeichnet**, daß das Meßgerät (18) einen Film zur Feststellung von Spuren ausgestrahlter Ionen aufweist, die das elektrische und das magnetische Feld passieren und den Film erreichen.

4. Methode zur Ionenimplantation in dem Ionen aus einer Plasmaquelle (25) heraus beschleunigt werden und dazu veranlaßt werden, auf einem Zielsubstrat (12) aufzutreffen, **dadurch gekennzeichnet**, daß die Ionendosierung einer bestimmten gewünschten Ionenart des Plasmas auf dem Substrat (12) in Übereinstimmung mit den Ausgaben (i) eines elektromagnetisch arbeitenden Ionenenergie-Analysators (14), der die gewünschte Ionenart zählt, nachdem sie aus einer Probe aller aus dem Plasma heraus beschleunigten Ionen geteilt wurden, und (ii) einer Ladungssammelelektrode (13), die eine entsprechende Probe aller aus dem Plasma heraus beschleunigten Ionen empfängt, wobei jede Probe zu den auf das Zielsubstrat auftreffenden Ionen korrespondiert, gesteuert wird, indem ein Verhältnis zwischen der Anzahl der gewünschten Ionen pro Zeiteinheit, die von dem Ionenenergie-Analysator (14) gemessen wurden und der Anzahl aller Ionen der Probe pro Zeiteinheit, die von der Ladungssammelelektrode (13) gemessen wurden, berechnet wird.

Revendications

1. Appareil d'implantation ionique comprenant :

une source de plasma (25) pour générer des

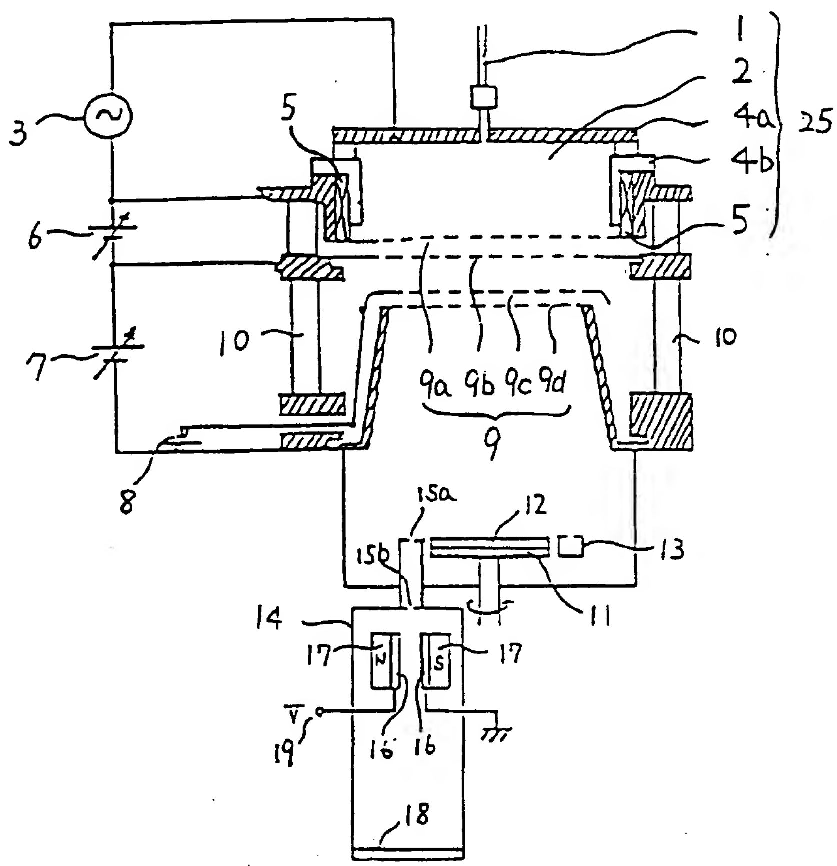
ions ;
un accélérateur d'ions (9) pour accélérer les ions ;
un support de substrat (11) prévu au niveau d'un emplacement qui est irradié par les ions accélérés ; et
un collecteur de charge (13) prévu au niveau d'un emplacement adjacent au support de substrat (11) qui est irradié par les ions accélérés ;
caractérisé :
par un analyseur d'énergie ionique électromagnétique (14) prévu au niveau d'un emplacement adjacent au support de substrat (11) qui est irradié par les ions accélérés et comprenant un moyen générateur de champ (15a, 15b, 16, 17) pour générer un champ électrique et un champ magnétique ayant des composantes perpendiculaires à la direction d'incidence des ions, et un moyen de mesure (18) pour mesurer, par unité de temps, le nombre d'ions d'un type souhaité, le moyen de mesure comportant une zone de détection comprenant différents points auxquels arrivent les ions ayant traversé le champ électrique et le champ magnétique, en fonction de la masse et de la charge des ions ; et en ce que le collecteur de charge (13) est conçu pour mesurer le nombre d'ions dont la quantité est pratiquement égale à celle des ions totaux irradiant l'analyseur d'énergie ionique électromagnétique (14) par unité de temps.

2. Appareil d'implantation ionique selon la revendication 1, dans lequel le moyen de mesure (18) est conçu pour mesurer la densité de courant d'un type souhaité d'ions ayant traversé le champ électrique et le champ magnétique.

3. Appareil d'implantation ionique selon la revendication 1, dans lequel le moyen de mesure (18) comporte un film pour détecter des traces des ions irradiants qui traversent le champ électrique et le champ magnétique et atteignent le film.

4. Procédé d'implantation ionique dans lequel des ions sont accélérés à partir d'une source de plasma (25) et amenés à frapper un substrat cible (12), caractérisé en ce que le dosage d'ions du substrat (12) avec une espèce particulière d'ions souhaitée dans le plasma est réglé conformément aux sorties (i) d'un analyseur d'énergie ionique électromagnétique (14) qui détecte ladite espèce d'ions souhaitée après avoir séparé les ions d'un échantillon du mélange d'ions accélérés à partir du plasma, et (ii) d'un collecteur de charge (13) qui reçoit un échantillon correspondant du mélange d'ions accélérés à partir du plasma, chaque échantillon correspondant aux ions irradiant ledit substrat cible, en calculant un rapport entre le nombre, par unité de temps, des ions de ladite espèce souhaitée, mesuré par l'analyseur d'énergie ionique électromagnétique (14) et le nombre, par unité de temps, des ions de tous les types contenus dans l'échantillon mesuré par le collecteur de charge (13).

Fig. 1


1
2
4a
25
4b
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9a 9b 9c 9d
9
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15a
12
15b
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14
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Fig. 2